P ENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

COMMUNICATION IN CASES FOR WHICH NO OTHER FORM IS APPLICABLE

To:
Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

Date of mailing (*day/month/year*) 22 November 2001 (22.11.01)	
Applicant's or agent's file reference P 99 027 WO	**REPLY DUE** see paragraph 1 below
International application No. PCT/DK00/00442	International filing date (*day/month/year*) 09 August 2000 (09.08.00)
Applicant TC ELECTRONIC A/S	

1. ☐ REPLY DUE within _____ months/days from the above date of mailing

☐ NO REPLY DUE, however, see below

☒ IMPORTANT COMMUNICATION

☐ INFORMATION ONLY

2. COMMUNICATION:

The International Preliminary Examining Authority has informed the International Bureau that the International Preliminary Examination Report dated 26 September 2001 has been cancelled and shall therefore be disregarded.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Beate GIFFO-SCHMITT
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 17 April 2001 (17.04.01)	
International application No. PCT/DK00/00442	**Applicant's or agent's file reference** P 99 027 WO
International filing date (day/month/year) 09 August 2000 (09.08.00)	**Priority date** (day/month/year) 09 August 1999 (09.08.99)
Applicant CHRISTENSEN, Knud, Bank et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

06 March 2001 (06.03.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Charlotte ENGER
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/11601 A1

(51) International Patent Classification[7]: G10H 1/00

(21) International Application Number: PCT/DK00/00442

(22) International Filing Date: 9 August 2000 (09.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
99202585.8 9 August 1999 (09.08.1999) EP

(71) Applicant *(for all designated States except US)*: **TC ELECTRONIC A/S** [DK/DK]; Sindalsvej 34, DK-8240 Risskov (DK).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **CHRISTENSEN, Knud, Bank** [DK/DK]; Skovvej 2, DK-8550 Ryomgaard (DK). **PEDERSEN, Kim, Rishoj** [DK/DK]; Skæring Sandager 54, DK-8250 Egå (DK). **LAVE, Morten** [DK/DK]; Jelshøjvænget 30, DK-8270 Højbjerg (DK).

(74) Agent: **PATENTGRUPPEN APS**; Arosgaarden, Aaboulevarden 23, DK-8000 Aarhus C (DK).

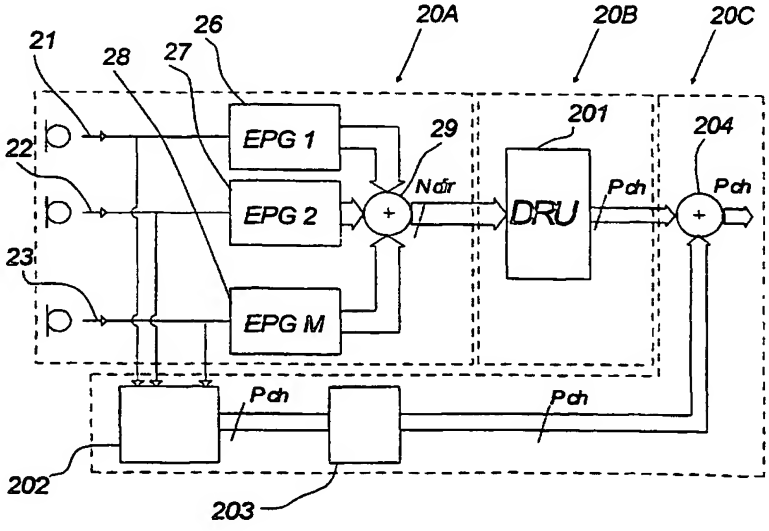
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: SIGNAL PROCESSING UNIT



(57) Abstract: The invention relates to a signal processing unit comprising at least one input (S), at least one of the said inputs (S) being connected to at least one early pattern generator (M), at least one early pattern generator (M) defining a predefined early pattern generation each of the said early pattern generators (M) establishing an output (d1, d2, d3, d4, ..., dN) having N directional components, each of the said directional components (N) of the said outputs (d1, d2, d3, d4, ...) being added to form at least one signal having N directional components. When representing each source output in a direction containing representation both directionality of the individual sound sources as well as the resulting directionality of the excited sound propagation may be contained and processed in a simple processing algorithm.

WO 01/11601 A1

— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

SIGNAL PROCESSING UNIT

Field of the invention

The invention relates to a signal processing unit according to claim1, a rendering unit according to claim 6, an early pattern mixer according to claim 9, a method of representing an audio-signal according to claim 11, a method of processing audio signals according to claim 13 and a signal processing unit according to claim 14.

Background of the invention

A reverberation imparting device is generally understood as a sound processing unit processing input signals representing an acoustic sound in such a way that the processed input signals are modified into an artificially established signal having desired acoustic properties as if the input signals were present in a certain room such as concert halls or the like.

Due to the relatively substantial requirements to the necessary hardware, the above-described technical discipline has been developed only recently.

The greatly improved facilities and possibilities of the commercially available digital signal processing processors and the correspondingly improved supporting A/D and D/A converting hardware have nevertheless provided a significant push-forward, as relatively large data streams may be processed, thus still improving the possibility of emulating the physical reality to a higher degree.

Nevertheless, it is still a fact that a true emulation of even a simple room may be quite complicated, both when considering the establishing of the theoretically necessary basics and the necessary supporting hardware.

A problem with the conventional technique, especially at the recording stage, is that naturalness is harder to obtain when the emulated sound image consists of several sound sources located in a simulated room.

Typically, sound rendering of multiple sound sources are generated by room simulators having one or two inputs and the processed input sound from the different sound sources basically shares the same early reflection pattern.

Consequently, the different sound sources are piled on top of each other in the resulting created sound image. The quality of this sound piling is far from convincing and simple individual panning of each source will still suffer from equal sound impression due to the shared early reflection pattern.

An additional problem will arise with multi-channel recordings as each source should be handled very carefully in order to achieve naturalness.

It is one object of the invention to provide a room simulation for multi-channel sound processing.

Summary of the invention

When, as stated in claim 1, the signal processing unit comprising

at least one input (S),
at least one of the said inputs (S) being connected to at least one early patterns generator (M),
at least one early pattern generator (M) defining a predefined early pattern generation each of the said early pattern generator (M) establishing an output (d1, d2, d3, d4,..,dN) having N directional components,
each of said directional components (N) of said outputs being added to form at least one signal having N directional components,

an advantageous signal processing unit has been obtained as the result of each source may be added in a relatively simple operation to form a true representation of a real sound field being established in a real room.

When representing each source output in a direction containing representation both directionality of the individual sound sources and the resulting directionality of the excited sound propagation may be contained and processed in a simple processing algorithm.

Moreover, the directional representation may be established according to psycho-acoustic knowledge about human hearing. Thus, a directional representation having most directional components concentrated at directions of which the human ear may acknowledge real differences.

According to the invention, as directional summing has proven to accumulate both the true 0^{th} order directional sound signal (i.e. the direct sound signal) as well as the more complex directional reverberation signal.

A further aspect of an embodiment of the invention is that the initial sound signal processing may be established more or less separately from the establishing of the tail-sound signal. Accordingly, the direct sound and the low order reflections may be established by carefully tuning all implied early pattern generators, mixing the different sound signal into one initial sound signal representing all source signals, and adding the sound tail to the signal after the rendering of the P-channel signal.

When, as stated in claim 2, the said unit further comprises a direction rendering unit (201) having an input for signals having N directional components,

the said direction rendering unit (201) establishing a P channel output signals on an output of the rendering unit (201) corresponding to input signals having N directional components, a further advantageous embodiment of the invention has been obtained.

Accordingly, a modular rendering of a P-channel sound image as a separate rendering stage provides a uniform rendering of all the input sources.

A further aspect of the above embodiment of the invention is that the early pattern module and the P-channel rendering stage may be adjusted and tuned individually.

A typical number of channels, i.e. the value of P, may vary from a stereo application having two channels or e.g. five channels up to e.g. twenty channels. Of course, the upper limit may be higher if appropriate.

When, as stated in claim 3, the said P channel output signals are established in such a way that they correspond to a P-channel trans- or bin-aural representation of the said N-directional input signal, an advantageous embodiment of the invention has been obtained.

When, as stated in claim 4, the said P channel output signals are established in such a way that they correspond to an experience-based P-channel representation of the said N-directional input signal, a further advantageous embodiment of the invention has been obtained.

Other rendering methods within the scope of the invention may be P- channel vector-based amplitude panning of the N-directional input or P-channel based intensity panning of the N-directional input or combinations of the above mentioned methods.

When, as stated in claim 5, the said signal processing unit further comprises a circuit (202, 203) having S inputs and P outputs, the said S inputs being individual input channels for S input sources,
the said P channel outputs comprising a P-channel late reverberation signal,
the said signal processing unit further comprising a summing unit (204)
the said summing unit (204) adding the said late reverberation signal to the the said established P-channel output signals of the said direction rendering unit (201), a further advantageous embodiment of the invention has been obtained.

Hence, the reverberation signals may be added subsequently to the rendering of the established sum signal without disturbing the sound image to the listener due to the fact that the reverberation sound tail is more or less diffuse and consequently not very directional.

The modular adding of the sound tail to the established P-channel signal provides a further possibility of separate tuning of the modules in a very advantageous way as the establishing of a sound tail signal may be tuned more or less independently of the tuning of the S source early pattern generation stage and the rendering stage.

It should be noted, that the above reverberation stage should be tuned to fit to the specific chosen number of channels P.

When, as stated in claim 6, the rendering unit comprises an input for N directional signals,
the said direction rendering unit (201) establishing a P channel output signal on an output of the rendering unit (201) corresponding to input signals having N directional components, a further advantageous embodiment of the invention has been obtained.

Accordingly, a rendering may be established independently of the location and number of all the input sources, as the rendering stage input is only one signal having N-directions.

A possible embodiment of the invention implies a five channel rendering of 10-directional signal where the directions of the input signal format are 0, +/-15, +/-30, +/-70, +/-110 and 180 degrees and the intended location of the five channels are 0, +/-30 and +/-110 degrees.

Obviously, several other directions and locations are applicable. A preferred embodiment comprises more than 20 directions.

Again, it should be noted that rendering of the sound signal may be established independently of how the input signal is generated.

When, as stated in claim 7, the said P channel output signals are established in such a way that they correspond to a P-channel trans-aural representation of the said N-directional input signal, a further advantageous embodiment of the invention has been obtained.

When, as stated in claim 8, the said P channel output signals are established in such a way that they correspond to an experience-based P-channel representation of the said N-directional input signal, a further advantageous embodiment of the invention has been obtained.

When, as stated in claim 9, the early pattern generation mixer (29) comprises M inputs, each input receiving early pattern signals comprising N directional components,
the said mixer (29) further comprising at least one output, the said at least one output transmitting an N-directional early patterns signal,
the said N-directional early patterns signal being established by adding the said M inputs, a further advantageous embodiment of the invention has been obtained as a mix of the very complex directional signal may be established by simple summing.

When, as stated in claim 10, the signal processing unit comprises
at least one input (S),
at least one of the said inputs (S) being connected to at least one space processor,
at least one space processor defining at least a generation of an early pattern
each of said space processors establishing an output (d1, d2, d3, d4,..,dN) having N directional components,
each of the said directional components (N) of the said outputs being added to form at least one signal having N directional components, a further advantageous embodiment of the invention has been obtained.

When, as stated in claim 11, the method of representing an audio-signal, wherein said signal is decomposed to a signal comprising N directional components, an advantageous signal representation has been obtained as a directional representation facilitates the possibility of a true and relatively simple processing of even very complicated audio signal scenarios.

Moreover, the approach of representing an audio signal as N directional components provides the possibility of treating both 0^{th} order signal, i.e. the direct sound, as well as more complicated reflection signals (i.e. 1^{st} and higher order reflections) in the same way and consequently under the same simulating conditions. Thus, the signal representation, according to the invention, provides a possibility of creating true correspondence between the direct sound and the resulting reflections in the sense that a signal may conveniently be represented as having both the direct sound and the reflections.

Moreover, the directional quantified representation provides a very distinct and accurate way of establishing a desired signal in a certain direction. It should be noted that traditional directional emulation is more or less based on individual panning of the different sound sources. According to the representation invention, the only uncertainty with respect to the directionality of the established sound signals refers to the method by which the directional representation is mapped (i.e. rendered) to a given number of channels. Nevertheless, it should be emphasised that the mutual directional spacing between sound signals is maintained as the rendering method is the same for all signals as has already been mentioned above. Consequently, the relative directional positioning is established by the signal format and not by sound engineers bound by traditional panning.

Thus, if distinct representations are desired, a high number of quantised directional components may be chosen.

Preferably, the N-directional components should of course represent a given signal at a specific geometrical position.

When, as stated in claim 12, the said signal is decomposed to a signal comprises N directional components by means of dedicated signal-processing means, an advantageous embodiment of the invention has been obtained as the signals may be established in real-time.

When, as stated in claim 13, the method of processing audio signals comprises M sub-signals, each sub-signal being represented as a signal having N directional components (d1, d2, d3, d4,..), the said sub-signals being added to form a sum-signal having N directional components (Σd1, Σd2, Σd3, Σd4,..,ΣdN), where Σdi(i=1..N) is the sum of signal components in one of the N directions, the said sum-signal representing the resulting audio signal, a further advantageous embodiment of the invention has been obtained as even very complicated audio-signals may be added by means of conventional summing means to form a complex and true signal which may establish several sound source positions in one signal.

When, as stated in claim 14, the signal processing unit comprises
at least one input (S),
at least one of the said inputs (S) being connected to at least one reverberation unit
at least one reverberation unit defining a predefined reverberation generation
each of the said reverberation units establishing an output (d1, d2, d3, d4,...) having N directional components,
each of said directional components (N) of said outputs being added to form at least one signal having N directional components, a further advantageous embodiment of the invention has been obtained as the signal-representation and signal-processing algorithm may basically be processed on both initial sound signals and the sound tail signal as well according to the invention.

The figure

The invention will be described below with reference to the drawings of which

fig.1 shows the basic understanding of a reverberated sound

fig.2 shows the basic principles of a sound processing device according to the invention

fig.3a-3c shows different sub-portions of the system according to the invention and

fig. 4a-4b illustrates early pattern generators according to the invention

Detailed description

According to most embodiments of the invention, it is the general approach that artificial generation of room simulated sound should comprise an early reflection pattern and a late sound sequence, i.e. a tail sound signal.

It should be noted that the invention is basically directed at the early reflection patterns, and consequently sound processing based on early reflections patterns within the scope of the invention.

Fig. 1 illustrates the basic principles of a conventional signal processing unit.

The circuit comprises an input 1 communicating with an initial pattern generator 2 and a subsequent reverberation generator 3. In addition, the initial pattern generator 2 and the subsequent reverberation generator 3 are connected to two mixers 4, 5 having output channels 6 and 7, respectively.

The initial pattern generator 2 generates an initial sound sequence with relatively few signal reflections characterising the first part of the desired emulated sound. It is a basic assumption that the initial pattern is very important as a listener establishes a subjective understanding of the simulated room on the basis of even a short initial pattern.

An explanation of this performance is that this signal reception corresponds to the actual sound propagation and reflection in a real life room.

Hence, reflections in a certain room will initially comprise relatively few reflections, as the first sound reflection, also called first order reflections, have to propagate from a sound source at a given position in the room to the listener's position via the nearest reflecting walls or surfaces. Compared with the overall heavy complexity of the technique, this sound field will be relatively simple and may therefore be emulated in dependency of the room and the position of the source and the listener.

Subsequently, and of course with some degree of overlapping, the next reflections will appear at the listeners position. These reflections, also called second order reflections, will be the sound waves transmitted to the position of the receiver via two reflecting surfaces.

Gradually, this sound propagation will increase in dependency of the room type, and finally the last reflected sound will be of a more diffuse nature as it comprises several reflections of several different orders at different times.

Apparently, the sound propagation will gradually result in a diffuse sound field and the sound field will more or less become a "sound soup". This diffuse sound field will be referred to as the tail sound.

If the walls have high absorption coefficients, the propagation will decrease quite fast after a short time period of time while the sound propagation will continue over a relatively long period of time if the absorption coefficients are low.

Fig. 2 illustrates the basic principles of a preferred embodiment of the invention.

For reasons of explaining, the shown embodiment of the invention has been divided into three modules 20A, 20B and 20C.

The first module 20A of the room simulator, according the embodiment shown, comprises M source inputs 21, 22, 23.

The source inputs 21, 22 and 23 are each connected to an early pattern generator 26, 27 and 28.

Each early pattern generator 26, 27 and 28 outputs M directional signals to a summing unit 29. The summing unit adds the signal components of each of the N predetermined directions from each of the early pattern generators 26, 27 and 27.

The summing unit output N directional signals to the module 20B comprising direction rendering unit 201.

The basic establishing of the N directional signals has been illustrated in fig. 3a.

Now returning to fig. 2, the direction rendering unit converts the N directional signal to a P channel signal representation.

The basic establishing of the P channels of module 20B has been illustrated in fig. 3b.

Moreover, the system comprises a third module 20C. The module 20C comprises a reverb feed matrix 202 fed by the M source inputs 21, 22, 23. The reverb feed matrix 202 outputs P channel signals to a reverberator 203 which, in turn, outputs a P channel signal to a summing unit 204.

Thus, the summing unit 204 adds the P channel output of the reverberator 203 to the output of the direction rendering unit 201 and feeds the P channel signal to an output.

The basic establishing of the P channels of module 20C has been illustrated in fig. 3c.

Before explaining the overall functioning of the algorithm, the basic functioning of the early pattern generators 26, 27, 28 and the summing unit 29 will be explained with reference to fig. 3a

According to fig. 3a, the module 20A comprises a number of inputs S1, S2, S3 and S4.

It should be noted that a number of four inputs have been chosen for the purpose of obtaining a relatively simple explanation of the basic principles of the invention. Many other input numbers may be applicable.

Each of the inputs are directed to an early pattern generator 26, 27 and 28. Each early pattern generator generates a processed signal specifically established and chosen for the source input S1, S2, S3 and S4. The processed signals, according to the shown embodiment, are established as a signal composed of seven signal components d1, d2, d3, d4, d5, d6 and d7. The seven signal components represent a directional signal representation of the established sound and the established signal contains both the direct sound and the initial reverberation sound.

A possible embodiment of the invention implies a five channel rendering of 10-directional signal where the directions of the input signal format are 0, +/-15, +/-30, +/-70, +/-110 and 180 degrees, and the intended location of the five corresponding loudspeakers are 0, +/-30 and +/-110 degrees according to ITU 775.

Obviously, several other directions and locations may be applicable. A preferred embodiment comprises more than 20 directions.

Accordingly, each of the inputs S1, S2, S3 and S4 may refer to mutually different locations of the input source to which the early pattern is generated.

Successively, the signals from each source are summed in summing unit 29. The summing is carried out as a simple adding of each signal component, i.e. d1:=d1(S1)+ d1(S2)+ d1(S3)+ d1(S4), d2:=d2(S1)+ d2(S2)+ d2(S3)+ d2(S4), d3:=d3(S1)+ d3(S2)+ d3(S3)+ d3(S4), d4:=d4(S1)+ d4(S2)+ d4(S3)+ d4(S4),

d5:=d5(S1)+ d5(S2)+ d5(S3)+ d5(S4), d6:=d6(S1)+ d6(S2)+ d6(S3)+ d6(S4) and d7:=d7(S1)+ d7(S2)+ d7(S3)+ d7(S4).

It should be noted that, even though undesired, according to the preferred embodiment of the invention, the signals d1,..,d7 may comprise tail sound components or even whole tail-sound. It should nevertheless be emphasised that according to the preferred embodiment of the invention such tail sound may advantageously be generated according to a relatively simple panning algorithm and subsequently added to the established summed initial sound signal as the established summed initial sound comprises the dominating room determining effects.

Moreover, it should be emphasised that a separate tuning of the resulting tail-sound signal is much easier when made separately from the individual tuning of the different source generators.

Turning now to module 20B, fig. 3b illustrates the basic functioning of the direction rendering unit 201.

According to the shown embodiment of the invention, the seven directional signal outputs from module 20A are mapped into a chosen multi-channel representation. According to the illustrated embodiment, the seven directional signals are mapped to a P=5 channel output.

According to a preferred embodiment of the invention, the type of multi-channel representation is a selectable parameter, both with respect to number of applied channels and to the type of speaker setup and the individual speaker characteristics.

The conversion into a given desired P channel representation may be effected in several different ways such as implying HRTF based (head related transfer function), a technique mentioned as Ambisonics, VBAP (vector based amplitude panning) or a pure experience based subjective mapping.

Turning now to fig. 3c module 20C is illustrated as having an input from each of the source inputs S1, S2, S3 and S4. The signals are fed to a reverb feed matrix 202 having five outputs, corresponding to the chosen channel number of the direction rendering unit 201. The five channel outputs are fed to a reverberation unit 203 providing a five channel output of subsequent reverberation signals.

The reverb feed matrix 202 comprises relatively simple signal pre-processing means (not shown) setting the gain, delay and phase of each input's contribution to each reverb signal and may also comprise filtering pre-processing means.

Subsequently, the reverberation unit 203 establishes the desired diffuse tail sound signal by means of five tank circuits (not shown) and outputs the resulting sound signal to be added to the already established space processed initial sound signal. According to the illustrated preferred embodiment of the invention, the tail sound generating means are added using almost no space processing due to the fact that a space processing of the tail sound signal according to the diffuse nature of the signal has little or no effect at all. Consequently, the complexity of the overall algorithm may be reduced when adding the tail sound separately and making the tuning much easier.

Moreover, it should be noted that the above mentioned separate generation of the tail-sound provides a more natural diffuse tail-sound due to the fact that the distinct comb-filter effect of the early pattern generator should preferably only be applied to the initial pattern in order to provide naturalness.

It should be noted that the above generation of subsequent reverberation signals, according to the present preferred embodiment, is generated independently of the initial sound generation. Nevertheless, it should be emphasised that the invention is in no way restricted to a narrow interpretation of the basic generation of a reverberation sound. Thus, within the scope of the invention, both the initial sound and the sound tail of each sound may of course be located within an artificial room and subsequently summed in a summing unit.

Turning now to fig. 4a, an early pattern generator, such as 26 of fig. 2, is illustrated in detail. The early pattern generator is one of four according to the above described illustrative embodiment of fig. 2, and each generator comprises a dedicated source input S1, S2, S3 and S4.

The shown early pattern generator 26 comprises a source input S1.

According to the shown embodiment, the source input is connected to a matrix of signal processing means. The shown matrix basically comprises three rows of signal processing lines, which are processed by shared diffusers 41, 42.

Accordingly, the upper row is fed directly from the input S1, the second row is fed through the diffuser 41, and the third row is fed through both diffusers 41 and 42.

Each row of the signal processing circuit comprises colour filters 411, 412, 413; 421, 422, 423; 431, 432, 433. According to the shown embodiment, colour filters of the same columns are identical, i.e. colour filter 411=421=431.

It should nevertheless be emphasised that the colour filters may of course differ within the scope of the invention.

Moreover each row comprises delay lines 4111, 4121 and 4131 which are serially connected to the colour filters 411, 412, 413. Finally, each column may be tapped via level and phase controllers such as 4000, 4001 and 4002. It should be noted that each level-phase controller 4000, 4001 and 4002 are tap specific.

Hence, the initial pattern generator 26 comprises a matrix which may comprise several sets of predefined presets by which a certain desired room may be emulated.

As already mentioned and according to the simplified embodiment of the invention, signals of the current predefined room emulation are tapped to the directional signal

representation of the present sound source S1. According to the illustrated programming, four signal lines are tapped to seven directional signal components. One signal, N13 of row 1, column 3, is fed to sound component 1, one signal, N21, is fed to signal component 3, and two signals, N11 and N22 are added to the sound component 4.

It should be noted that each tapped signal has consequently been processed through one of three combinations of diffusers, one of three types of predefined colour filters EQ, a freely chosen length of delay line and a freely chosen level and phase output.

Obviously, several other combinations and number processing elements are applicable within the scope of the invention.

According to one of the preferred embodiment of the invention, a separate row with a level-phase controller 4002 should be tapped and determine the direct sound. When integrating the direct sound into the early pattern generation, the location of both the direct sound as well as the corresponding EPG and reverberation sound signals may be mapped into the sound signal representation completely similar to the desired directionality irrespective of directional resolution and complexity.

Evidently, the directional signal representation components usually comprise signals fed to each component 1-7 and not only the illustrated three.

It should be noted, that the chosen topology of the early pattern generator within the scope of the invention may be chosen from a set of more or less equivalent topologies. Moreover, the signal modifying components may be varied, if e.g. a certain degree of tail-sound is added before or after tapping.

As the illustrated early pattern generator comprises linear systems, it will be possible to interchange the components, e.g. the colour filters EQ may be interchanged with the diffusers DIF.

Fig. 4b illustrates a further possible embodiment of the early pattern generator, comprising colour filters EQ placed in the feed line to each row and diffusers DIF placed in each column in each row.

Likewise, the number of columns and rows may vary depending of the system requirements. In a possible embodiment only one column of delay lines with corresponding colour filters or diffusers is utilised. Moreover, additional components, additional diffusers, additional different types of colour filters, etc. may be chosen.

Finally it should be mentioned that, according to a preferred embodiment of the invention, the number of directions, i.e. signal components, should be not less than twelve, and the established reflections of each early pattern generator should not be less than 25.

The basic presetting of each early pattern generator may initially be determined by known commercially available ray tracing or room mirroring tool, such as ODEON.

CLAIMS

1. Signal processing unit comprising

at least one input (S),

at least one of the said inputs (S) being connected to at least one early patterns generator (M),

at least one early pattern generator (M) defining a predefined early pattern generation

each of the said early pattern generator (M) establishing an output (d1, d2, d3, d4,...) having N directional components,

each of said directional components (N) of said outputs (d1, d2, d3, d4,...) being added to form at least one signal having N directional components.

2. Signal processing unit according to claim 1, wherein the said unit also comprises a direction rendering unit (201) with an input for signals having N directional components,

the said direction rendering unit (201) establishing a P channel output signals on an output of the rendering unit (201) corresponding to input signals having N directional components.

3. Signal processing unit according to claim 2, wherein said P channel output signals are established in such a way that they correspond to a P-channel trans- or bin aural representation of the said N-directional input signal.

4. Signal processing unit according to claim 2, wherein the said P channel output signals are establishes in such a way that it corresponds to an experience-based P-channel representation of the said N-directional input signal

5. Signal processing unit according to claims 1 to 4, wherein the said signal processing unit also comprises a circuit (202, 203) having S inputs and P outputs, the said S inputs being individual input channels for S input sources,

the said P channel outputs comprising a P-channel late reverberation signal,

the said signal processing unit further comprising a summing unit (204)

the said summing unit (204) adding the said late reverberation signal to the said established P-channel output signals of the said direction rendering unit (201)

6. Rendering unit comprising an input for N directional signals,

the said direction rendering unit (201) establishing a P channel output signal on an output of the rendering unit (201) corresponding to input signals having N directional components.

7. Rendering unit according to claim 6, wherein the said P channel output signals are established in such a way that they correspond to a P-channel trans-aural representation of the said N-directional input signal.

8. Rendering unit according to claim 6, wherein the said P channel output signals are established in such a way that it corresponds to an experience-based P-channel representation of the said N-directional input signal

9. Early pattern generation mixer (29) comprising

M inputs, each input receiving early pattern signals comprising N directional components,

the said mixer (29) further comprising at least one output, the said at least one output transmitting an N-directional early patterns signal,

<

The said N-directional early pattern signal being established by adding the said M inputs.

10. Signal processing unit comprising

at least one input (S),

at least one of the said inputs (S) being connected to at least one space processor,

at least one space processor defining at least a generation of an early pattern

each of the said space processors establishing an output (d1, d2, d3, d4,..dN) having N directional components,

each of the said directional components (N) of the said outputs (d1, d2, d3, d4,...) being added to form at least one signal having N directional components.

11. Method of representing an audio-signal, wherein the said signal is decomposed to a signal comprising N directional components.

12. Method according to claim 11, wherein the said signal is decomposed to a signal comprising N directional components by means of dedicated signal-processing means.

13. Method of processing audio signals comprising M sub-signals, each sub-signal being represented as a signal having N directional components (d1, d2, d3, d4,..,dN), the said sub-signals being added to form a sum-signal having N directional components (Σd1, Σd2, Σd3, Σd4,..,ΣdN) where Σdi(i=1..N) is the sum of signal

components in one of the N directions, the said sum-signal representing the resulting audio signal.

14. Signal processing unit comprising

at least one input (S),

at least one of the said inputs (S) being connected to at least one reverberation unit

at least one reverberation unit defining a predefined reverberation generation

each of the said reverberation units establishing an output (d1, d2, d3, d4,..,dN) having N directional components,

each of the said directional components (N) of the said outputs (d1, d2, d3, d4,...) being added to form at least one signal having N directional components.

1/4

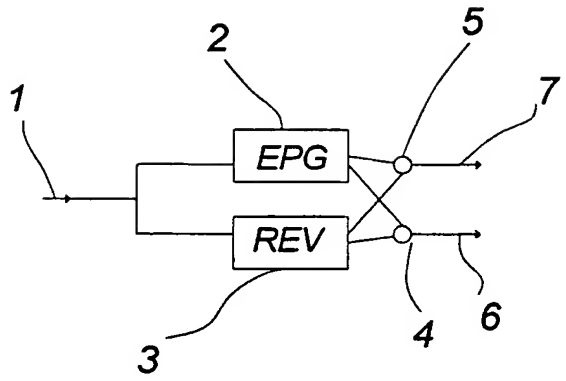

1
2
3
4
5
6
7
EPG
REV

Fig.1

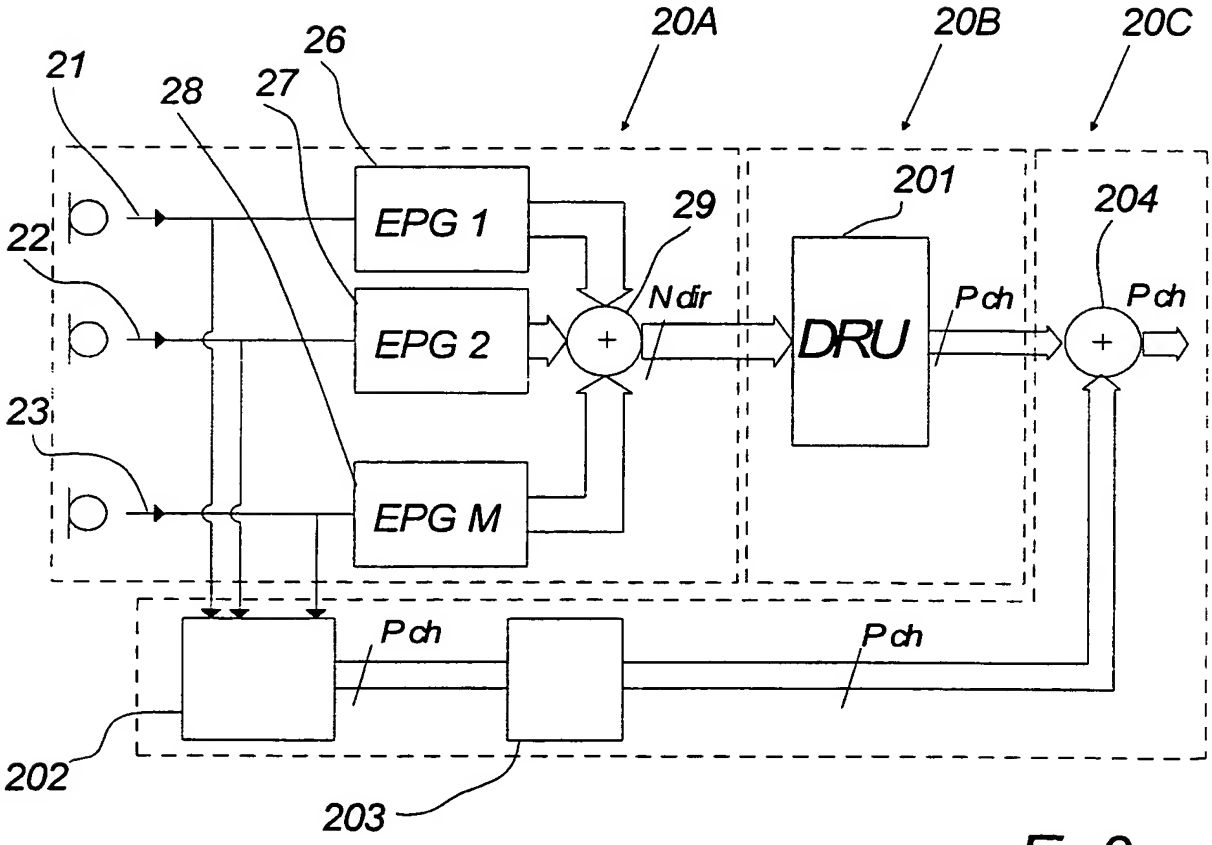

20A
20B
20C
21
22
23
26
27
28
29
201
204
EPG 1
EPG 2
EPG M
Ndir
DRU
Pch
Pch
Pch
Pch
202
203

Fig.2

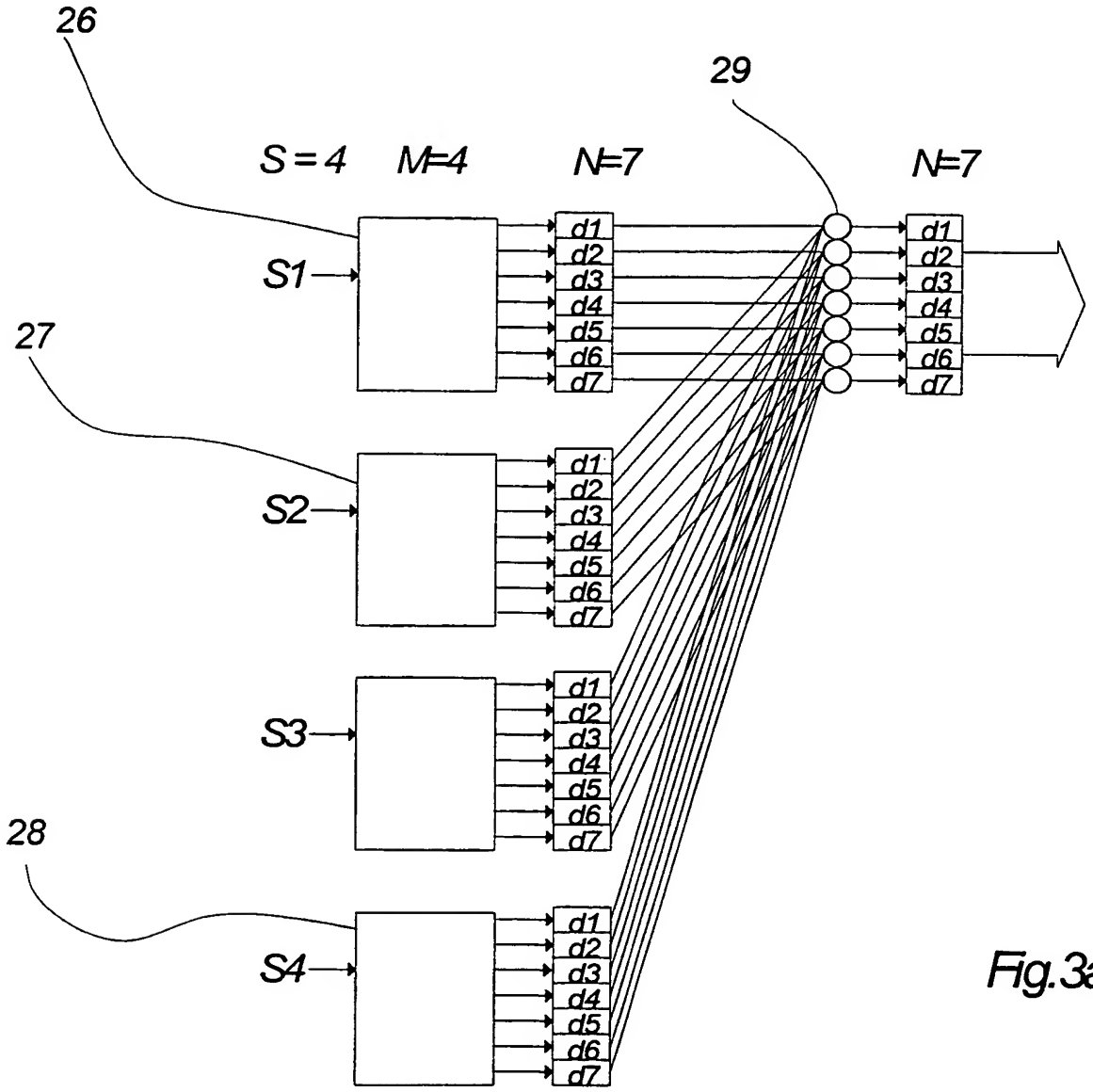


Fig.3a

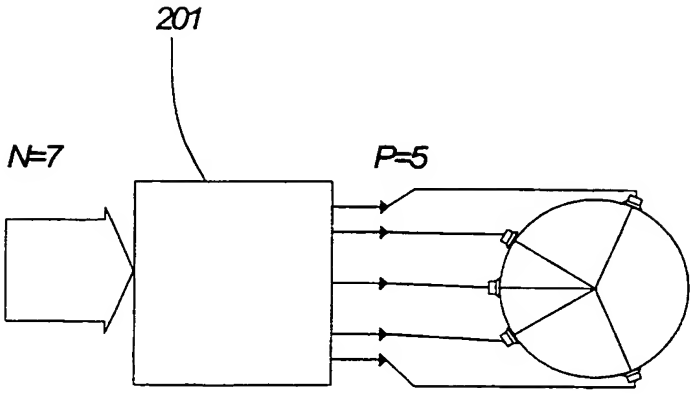


Fig.3b

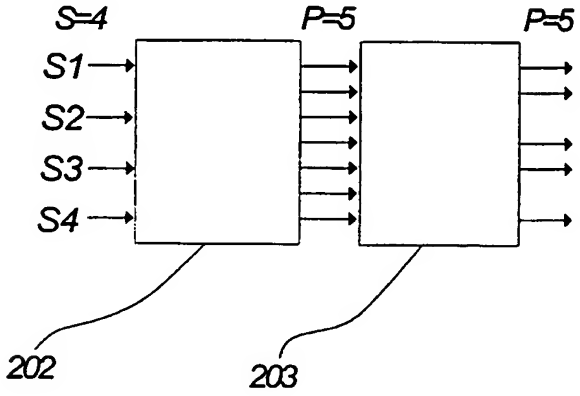


Fig.3c

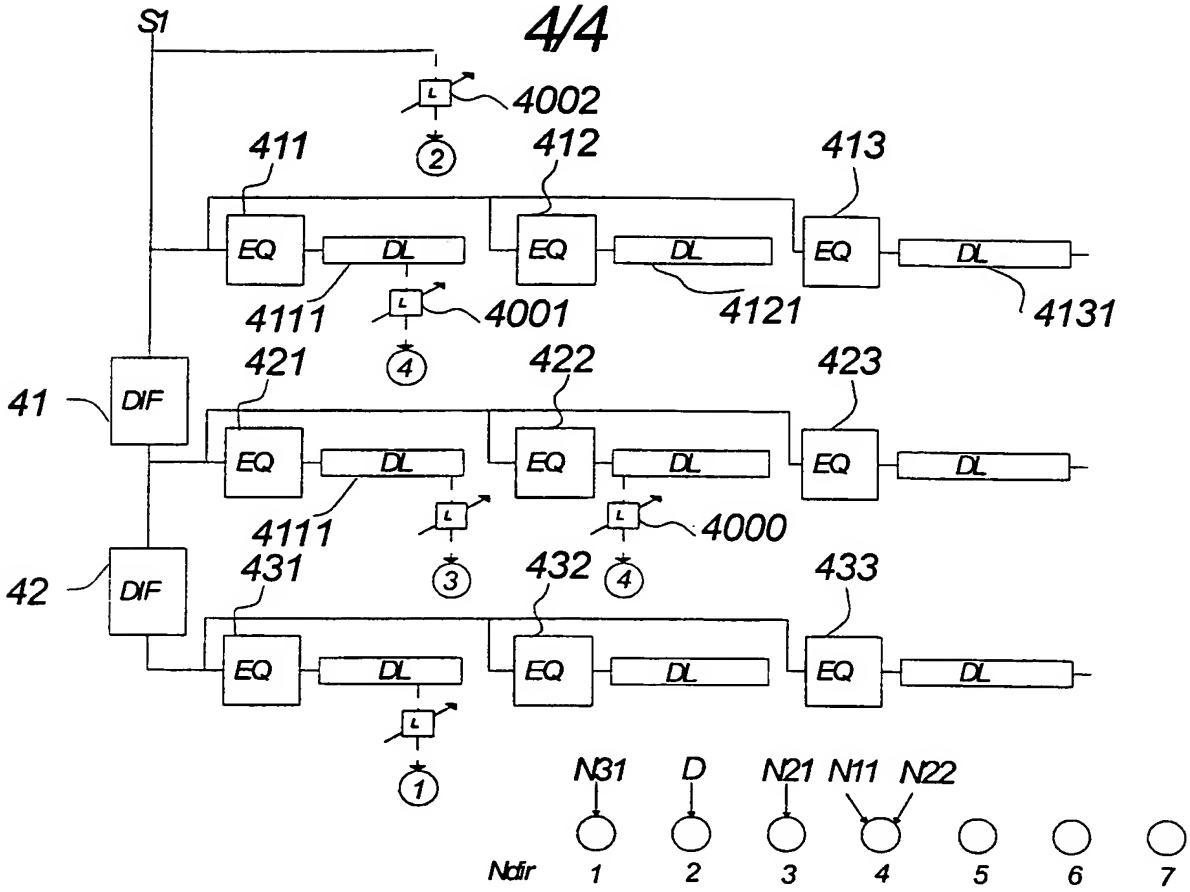

S1
4002
411
412
413
EQ
DL
4111
4001
4121
4131
41
DIF
421
422
423
4000
42
431
432
433
N31
D
N21
N11
N22
Ndir
1
2
3
4
5
6
7

Fig.4a

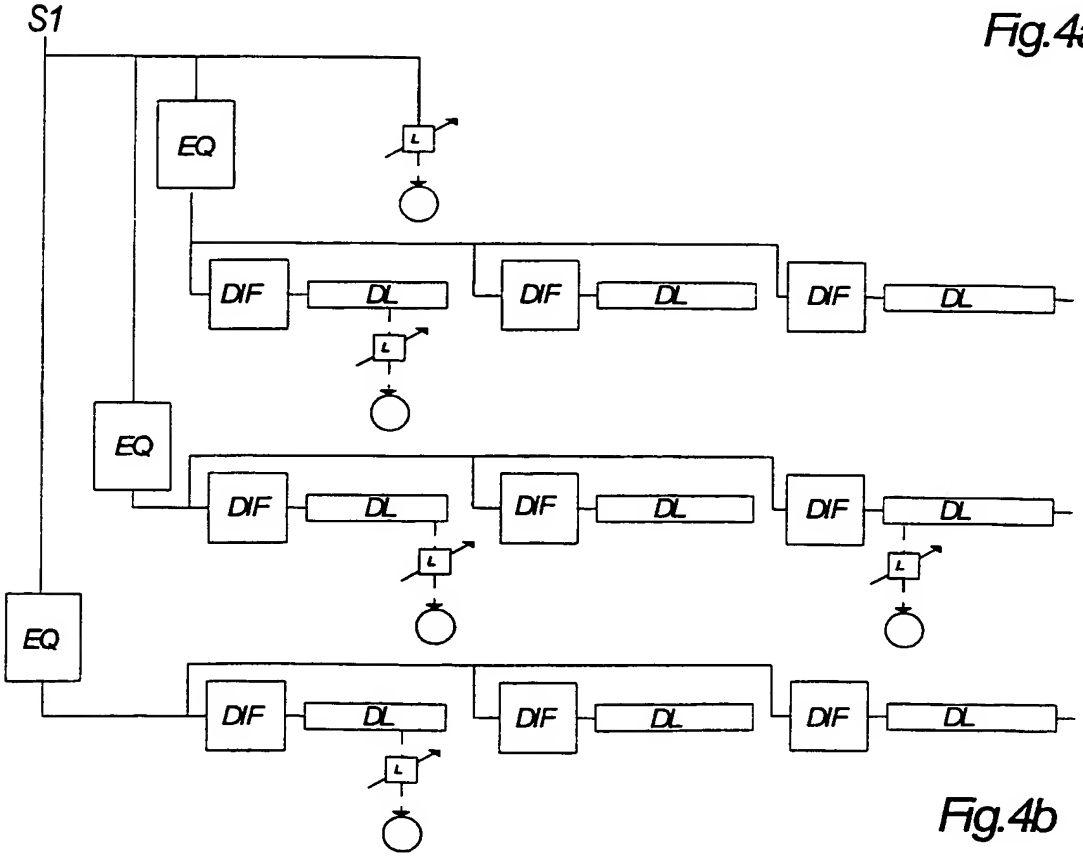

S1
EQ
DIF
DL

Fig.4b

INTERNATIONAL SEARCH REPORT

Intern. Application No
PCT/DK 00/00442

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G10H1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G10H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 563 929 A (YAMAHA CORP) 6 October 1993 (1993-10-06) column 2, line 35 - line 52 column 5, line 10 -column 6, line 35; figure 1	1-14
A	WO 86 02791 A (UNIV NORTHWESTERN) 9 May 1986 (1986-05-09) page 8, line 28 -page 11, line 36; figure 2A	1-14
A	US 5 585 587 A (TORIMURA HIROYUKI ET AL) 17 December 1996 (1996-12-17) column 6, line 40 -column 7, line 25; figures 1,2,5	1-14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 November 2000	01/12/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pulluard, R

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information [redacted] patent family members

Intern[redacted] pplication No
PCT/DK 00/00442

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0563929 A	06-10-1993	JP 2973764 B	08-11-1999
		JP 6051759 A	25-02-1994
		JP 5300597 A	12-11-1993
		DE 69322805 D	11-02-1999
		DE 69322805 T	26-08-1999
		US 5822438 A	13-10-1998
		US 5581618 A	03-12-1996
		SG 52771 A	28-09-1998
WO 8602791 A	09-05-1986	US 4731848 A	15-03-1988
		AT 57281 T	15-10-1990
		DE 3580035 D	08-11-1990
		EP 0207084 A	07-01-1987
		JP 62501105 T	30-04-1987
US 5585587 A	17-12-1996	JP 7092968 A	07-04-1995
		US 5771294 A	23-06-1998

TENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P 99 027 WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00442	09/08/2000	09/08/1999
International Patent Classification (IPC) or national classification and IPC G10H1/00		
Applicant TC ELECTRONIC A/S et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
06/03/2001	30.11.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Hartberger, J Telephone No. +49 89 2399 2193

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK00/00442

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-17	as originally filed				

Claims, No.:

1-6	as received on	10/11/2001	with letter of	08/11/2001	

Drawings, sheets:

1/4-4/4	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☒ the claims, Nos.: 7-14

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-5
	No:	Claims 6
Inventive step (IS)	Yes:	Claims 1-5
	No:	Claims
Industrial applicability (IA)	Yes:	Claims 1-6
	No:	Claims

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following document:
   D1 : WO-A-86/02791
   D2 : US-A-5 585 587

2. Irrespective of the objection in following paragraph 7.3 the following assessments are made under the assumption that the subject-matter of claim 1 concerns a circuit structure as shown in Fig. 2, and in particular Fig. 3a of the present application.

   The subject-matter of Claim 1 is different over D1, which is considered as the closest prior art, in particular with respect to Fig. 2A, in that a plurality of individual inputs (see Fig. 2: 21, 22, 23) or Fig 3a: S1,...,S4) is connected to and directionalized by means of corresponding early reflection pattern generators (26,27,28).

   Such a solution in not known from the available prior art, including D1 and D2, nor does it appear to be rendered obvious therefrom.

   Hence the solution to this problem proposed in claim 1 of the present application is considered as being new and as involving an inventive step (Article 33 (2) and (3) PCT).

2.1. Claims 2 to 5 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step (Articles 33 (2) and (3) PCT).

3. Since the "sub signals" are not further specified, they may be any signals within the circuitry, and thus claim 6 appears to claim a particular portion of the circuitry, respectively the operation which is performed in D1, Fig. 2A, i.e. the combination the N-directional components contained in M (+1 sub-) signals, performed by the components 22, 24 and 26 (see also following paragraph 7.1).

hence, using the wording of Claim 6, D1, see Fig. 2A and the description page 9, lines 18 to page 11, line 36, discloses a
Method of processing audio signals comprising M sub-signals (output from directionalizer 22 and the M directionalizers 24), each sub-signal being represented as a signal having N directional components (outputs from 22, 24), the said sub-signals being added (26) to form a sum-signal having N directional components 1,2,... ,N, where i (I=1,., N), is the sum of signal components of in one of the N directions, the said sum-signal representing the resulting audio signal.

Claim 6 thus lacks novelty and does therefore not meet the requirements of Article 33(2) PCT.

Re Item VII

Certain defects in the international application

4. A document reflecting the prior art described on page 1 and 2, is not identified in the description (Rule 5.1(a)(ii) PCT).

   Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed e.g. in D1 and D2 is not mentioned in the description, nor are these documents identified therein.

5. The description is not in conformity with the claims as required by Rule 5.1(a)(iii) PCT.

6. Independent Claims 1 and 6 are not in the two-part form in accordance with Rule 6.3(b)(i) and (ii) PCT, which in the present case would be appropriate in the light of the disclosure of D1, see paragraph 3 above.

Re Item VIII

Certain observations on the international application

7. Claims 1 and 6 do not meet the requirements of Article 6 PCT.

7.1 The wording "sub signals" per se is not clear since it does not unambiguously define individual "source inputs" (from external) as disclosed in the description, see e.g. page 10, line 31, as shown in e.g. Fig. 2, and hence "sub signals" may concern any arbitrary chosen signals within the circuitry. This ambiguity appears to lead to the objection in paragraph 3 above.

7.2 The subject-matters of Claims 1 and 6 are different in that "a plurality of inputs are connected to (at least one) early reflection pattern generator" are claimed in Claim 1 but not in Claim 6.

However, these features appear to be essential to the definition of the present invention. Since independent Claims 6 does not contain this feature, it does not meet the requirement following from Article 6 PCT taken in combination with Rule 6.3(b) PCT that any independent claim must contain all the technical features essential to the definition of the invention.

7.3 The relationship between the pluralities of "inputs" and "early reflection pattern generators" is not clear from the wording of Claim 1. It appears in the light of the description, see e.g. page 11, lines 1-2, that each one of the (source) inputs is connected an early pattern generator. However, a solution, with one (of the) input(s) connected to more than one early reflection pattern generators, which is presently included in the wording of claim 1 "a plurality of said inputs each being connected to at least one (i.e one or more) early reflection pattern generator" appears not to be supported by the description as originally filed.

AMENDED CLAIMS (011107)

1. Signal processing unit comprising

a plurality of inputs (S1, S2, S3, S4),

a plurality of said inputs (S1, S2, S3, S4) each being connected to at least one early reflection pattern generator (26, 27, 28),

a plurality of said at least one early reflection pattern generators (26, 27, 28) defining a predefined early reflection pattern generation

each of the said early reflection pattern generators (26, 27, 28) establishing an output having N directional components d1, d2, d3, d4,...,

each of said directional components of said outputs being added to form at least one signal having N directional components $\Sigma d1$, $\Sigma d2$, $\Sigma d3$, $\Sigma d4$,..,ΣdN where $\Sigma di(i=1..N)$ is the sum of signal components in one of the N directions, the said sum-signal representing the resulting audio signal

2. Signal processing unit according to claim 1, wherein the said unit also comprises a direction rendering unit (201) with an input for signals having N directional components,

the said direction rendering unit (201) establishing a P channel output signals on an output of the rendering unit (201) corresponding to input signals having N directional components.

3. Signal processing unit according to claim 2, wherein said P channel output signals are established in such a way that they correspond to a P-channel trans- or bin aural representation of the said N-directional input signal.

4. Signal processing unit according to claim 2, wherein the said P channel output signals are established in such a way that they correspond to an experience-based P-channel representation of the said N-directional input signal.

5. Signal processing unit according to claims 1 to 4, wherein the said signal processing unit also comprises a circuit (202, 203) having S inputs and P outputs, the said S inputs being individual input channels for S input sources,

the said P channel outputs comprising a P-channel late reverberation signal,

the said signal processing unit further comprising a summing unit (204)

the said summing unit (204) adding the said late reverberation signal to the said established P-channel output signals of the said direction rendering unit (201).

6. Method of processing audio signals comprising a plurality of M sub-signals, each sub-signal being represented as a signal having a plurality of N directional components d1, d2, d3, d4,..,dN, the said sub-signals being added to form a sum-signal having N directional components $\Sigma d1$, $\Sigma d2$, $\Sigma d3$, $\Sigma d4$,..,ΣdN where $\Sigma di(i=1..N)$ is the sum of signal components in one of the N directions, the said sum-signal representing the resulting audio signal.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P 99 027 WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/DK 00/ 00442	09/08/2000	09/08/1999
Applicant		
TC ELECTRONIC A/S		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.